

NNDEN/47

**NEUTRON NUCLEAR DATA
EVALUATION NEWSLETTER**

**NEA DATA BANK
BANQUE DE DONNÉES DE L'AEN**

March 1994

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NEUTRON NUCLEAR DATA EVALUATION NEWSLETTER

NNDEN/47

The Newsletter reports:

- Evaluation work on particular nuclides
- Development of codes for nuclear model calculations, and other codes needed for nuclear data work.
- Publications relevant to the neutron data field.

Contributions have been received from:

BELARUS	Radiation Physics and Chemistry Problems Institute Minsk	11
BULGARIA	Institute for Nuclear Research and Nuclear Energy	13
CHINA	Chinese Nuclear Data Centre, Institute of Atomic Energy, Beijing	14
	CNDC, Guangxi Univ., Zhengzhou Univ., Nankai Univ.	18
FRANCE	Centre d'Etudes Nucleaires de Cadarache	21
GERMANY	Kernforschungszentrum Karlsruhe GmbH, Karlsruhe	22
ITALY	Ente Nazionale Energie Alternative, Bologna	24
INDIA	Bhabha Atomic Research Centre	33
JAPAN	Japanese Nuclear Data Committee (Nuclear Data Center, JAERI)	34
NETHERLANDS	Stichting Energieonderzoek Centrum Nederland, Petten	39
POLAND	Soltan Institute for Nuclear Studies, Warsaw	42
ROMANIA	Institute of Physics and Nuclear Engineering /Institute of Atomic Physics	43
SLOVAKIA	Institute of Physics, Bratislava	44
UNITED KINGDOM	Nuclear Physics Laboratory, Oxford	46

USA	Los Alamos National Laboratory	48
USA	National Nuclear Data Center, Brookhaven	52
IAEA	Nuclear Data Section, Vienna	53
OECD/NEA	NEA Evaluation Activities	56
	New at the Data Bank	60
	NEA Online Services	63

The next issue of NNDEN has been scheduled for March 1995. Contributors are asked to send in their reports by 1st February 1995.

Index to data referenced in NNDEN/47

- A) COMPLETED
 B) IN PROGRESS
 C) PLANNED IN THE NEAR FUTURE

NUCLIDE	DATA TYPE	ENERGY	PAGE		
			A	B	C
H 1	cross sections, angular distributions	20 MeV - 1 GeV		37	
H 2	extension of ENDF/B-VI to higher energy	< 40 MeV		51	
Be 9	622 keV resonance transitions		37		
C 12	nucleon induced reactions			37	
C 12	cross sections	20 - 50 MeV		37	
C nat	photo-reaction cross section	10 - 140 MeV	35		
N 14	cross sections		50		
N 14	ENDF/B-VI.2 evaluation	< 2.5 MeV	51		
N nat	photo-reaction cross section	10 - 140 MeV	35		
O 16	434 keV resonance transitions		34		
O 16	(n, γ α) cross section	14.7 MeV	44		
O nat	photo-reaction cross section	10 - 140 MeV	35		
Mg 24	658 keV resonance transition		34		
Al	p, α , γ emission spectra	< 200 MeV		51	
Al 27	extension of ENDF/B-VI to higher energy	< 40 MeV		51	
Al 27	(n, x γ)	\leq 400 MeV	50		
Al 27	nucleon induced reactions			37	
Al 27	cross section and emission spectra	< 1 GeV	36		
Si 28	180 keV resonance transitions		34		
Si 32	1 - 3 keV resonance transitions		34		
S 32	203 keV resonance transitions		34		
Cl	evaluation, many data		14		
Ti 46	(n,2n) cross section		54		
Cr	library intercomparison		14		
Cr 52	(n,p) cross section	13 - 16.6 MeV		42	
Cr 52	library intercomparison		39		

Cr 53	(n,p) cross section	13 - 16.6 MeV		42
Fe	p, α , γ emission spectra	< 200 MeV		51
Fe	EFF-1/EFF-2.3 intercomparison		39	
Fe	JEF-2, ENDF/B-VI shielding benchmark		28	
Fe	library intercomparison		14	
Fe	JENDL-3 shielding benchmark			28
Fe 54	(n,2n)Fe-53m+g cross section		54	
Fe 56	evaluation, many data		14	
Fe 56	cross section fluctuations		22	
Fe 56	revised evaluation		25	
Fe 56	resonance parameters and covariances	< 862 keV	22	
Fe 56	(n,x α)	< 30 MeV	50	
Fe 56	radiation damage; PKA spectrum		28	
Fe 56	library intercomparison		39	
Fe 56	extension of ENDF/B-VI to higher energy	< 40 MeV		51
Fe isotopes	EFF-2 data processed for sensitivity analysis		27	
Co	p, α , γ emission spectra	< 200 MeV		51
Co 59	extension of ENDF/B-VI to higher energy	< 40 MeV		51
Co 59	(n, α)	< 30 MeV	50	
Co 60	(n,p) cross section		35	
Ni	library intercomparison		14	
Ni 58	resonance parameters and covariances			23
Ni 58	library intercomparison		39	
Ni 60	library intercomparison		39	
Ni 60	resonance parameters and covariances			23
Zn 64	(n,p) cross section	13 - 16.6 MeV		42
Zn 66	(n,p) cross section	13 - 16.6 MeV		42
Zn 67	(n,p) cross section	13 - 16.6 MeV		42
Zn 68	(n,p) cross section	13 - 16.6 MeV		42
Zr 90	(p,xn), (p,xp)		49	
Zr nat	(n,2n) cross section		33	
Ga	evaluation, many data		14	
Mo isotopes	reevaluation		25	
Tc 98	nuclear structure		25	
Tc 100	nuclear structure		25	

Xe isotopes	(γ ,n) cross section		24	
Sm isotopes	level density parameters		25	
Sm 147	resonance parameters		13	
Sm 148	resonance parameters		13	
Gd 157	radiative strength		39	
Lu	evaluation, many data		14	
Hf 179	(n,2n) ^{178m2Hf} , (n,n' ^{179m2Hf} cross sections		49	
W isotopes	photo absorption cross section		24	
W 183	multiparticle reaction cross sections	< 30 MeV		33
W 184	multiparticle reaction cross sections	< 30 MeV		33
W 184	multiparticle reaction cross sections	< 30 MeV		33
Os isotopes	level density parameters		25	
Hg	evaluation, many data		14	
Tl	evaluation, many data		14	
Pb	p, α , γ emission spectra	< 200 MeV		51
Pb nat	revision of evaluation		39	
Pb 207	(n,xn γ)	< 200 MeV	50	
Pb 208	extension of ENDF/B-VI to higher energy	< 40 MeV		51
Pb 208	(p,xn), (p,xp)		49	
Pb 208	scattering		48	
Pb 208	(n,xn γ)	< 200 MeV	50	
Pb 208	γ emission	14.7 MeV		45
Tl	evaluation, many data		14	
Bi 209	multineutron emission cross section		33	
Bi 209	optical parameters		35	
U 233	resonance parameters		37	
U 233	evaluation		54	
U 234	cross sections	thermal	11	
U 235	resonance parameters			13
U 238	(n,sct)		11	
U isotopes	(n,f) cross section			51
Pu 233	(n,f) cross section	1 - 100 keV	21	
Pu 239	resonance parameters			13
Pu 239	(n,2n) cross section		11	
Pu 239	reevaluation			21

Pu 239	resonance parameters	1 - 2.5 keV	35		
Pu 240	reevaluation				21
Pu 241	resonance parameters	0.02 - 20 eV	36		
Pu isotopes	(n,f) cross section			51	
Cm	(n,f) cross section		11		
actinides	(minor) many data				12
actinides	(minor) nu-bar, prompt fission n spectra		12		
actinides	(n,2n) cross section		11		
actinides	nu-bar, spectra for n and γ			12	
actinides	(Z-even,N-odd) (n,2n)	threshold		12	
actinides	(n,f) cross section	60 -200 MeV			12
actinides	nu-bar, spectra for n and γ	> 20 MeV			12
actinides	(n,abs) cross section	8 - 14 MeV	11		
actinides	prompt fission n spect., neutron multiplicities			50	
fissile mat.	code: cross section and neutron spectra	3 - 20 MeV		15	
fissile mat.	code: neutron induced reaction data	< 20 MeV	14		
fission prod.	optical model parameters		34		
fission prod.	review of JENDL-3, JEF-2, ENDF/B-VI		34		
Fission lib.	time-dependent cross sections for fission reactors		28		
Fusion lib.	time-dependent cross sections for fission reactors		29		
many	activation cross sections for fusion		49		
many	A<40 : resonance transitions		36		
many	code: charged particle induced reaction data	< 30 MeV	14		
many	(A~50) optical model parameters for (n, α)			43	
many	Fe-54 to Bi-209 : (p,p'x) cross sections	62 - 200 MeV	36		
many	(Z=82-98) fission barrier parameter library		54		
many	(A \geq 100) optical model params for incident α			43	
many	(A=41-253): level density parameters		37		
many	prompt fission n and γ spectra and multiplicities		11		
many	(Z=23-28) pre-equilibrium neutron emission	14 MeV		47	
many	(Z=23-28) fast neutron induced cross sections			43	
many	code: neutron or charged particle induced reactions	< 50 MeV	15		
many	(A=74-165) γ branching ratios		54		
many	(α ,n), (n, α) cross sections			47	

many	(n,n'), (n,p)	14 MeV	47	
many	code: photo-reaction data	< 30 MeV	14	
many	code: intermediate/high energy data	> 20 MeV		15
many	photon production cross section and spectra			41
shielding mat	JEF-2.2 data processed into VITAMIN-J		27	
Struct. mat.	JEF-2.2 data processed into library for ECCO		27	
transactinide	prompt fission n spectra, neutron multiplicities			50
WIMS-D4	status report		54	
WRENDATA	World Request List		54	
CENDL	fission yields			16
CENPL (III)	evaluated nuclear parameters			18
EAF-4	status report		39	
EAF-4	extension to EAF-3			41
EFF-2	intercomparison with FENDL-1		40	
EFF-2	pointwise library for MCNP			26
EFF-2	COVNET: group library of covariance data		26	
EFF-2	GEFF-2: group library for fusion neutronics			26
EFF-2.3	status report		39	
EFF-2.4	status report		39	
EFF-3	improvements relative to EFF-2.4			41
EFF/EAF	overview report		39	
ENDF/B-VI	decay data evaluation		49	
ENDF/B	(IV,V,VI) fission products; neutron absorption		48	
ENDF/B-VI	data testing		50	
ENDF/B-VI	yields		48	
ENDF/B-VI	key changes from ENDF/B-V		49	
ENDF/B-VI	energy balance		50	
ENDF/B-VI	cumulative and independent yields		51	
ENDF/B-VI	Release 2		52	
IRDF-90	collapsed into VITAMIN-J group structure		27	
JEF-2	validation	thermal, fast		21
JENDL	actinides: summary	< 20 MeV	36	
JENDL	high energy: summary	< 1 GeV	36	
JENDL-3	fission products: eval. of resonance parameters		34	

JENDL-3	review of gamma production data		35		
JENDL-3	summary of revision work		35		
JENDL-3	eval. of fusion file			38	
JENDL-3	revision work for JENDL-3.2			38	
library	JEF-2.2/ENDF/B-VI : group library for FLUKA			27	
library	JEF-2.1/ENDF/B-VI/LLNL : group library for FLUKA		27		

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I RECENT PUBLICATIONS AND REPORTS

Maslov V.M. "Curium Fission Cross Section Analysis", *Annals of Nucl. Energy* V.20, No.3, pp.163-166, 1993.

Maslov V.M. "Pairing Effects in $^{239}\text{Pu}(n,2n)$ Reaction Cross Section", accepted by *Z. Phys.* to appear in A345, 1994.

Maslov V.M. "Pairing Effects in Actinide (n,2n) Reaction Cross Sections", submitted to the Int. Conf. on Nucl. Data for Sci. and Tech., 9-13 May, 1994, Gatlinburg, Tennessee, USA.

Porodzinskij Yu.V., Sukhovitskij E.Sh. "Nuclear Dynamics and Analysis of Neutron Scattering by ^{238}U " *Yadernaya Fyzika* V.56, pp.64-71, 1993 (in Russian).

Porodzinskij Yu.V., Sukhovitskij E.Sh. "Neutron Absorption Cross Section for Actinides in the Energy Range 8-14 MeV", submitted to *Yadernaya Fizika*.

Porodzinskij Yu.V., Sukhovitskij E.Sh. "Effective Account of Hexadecupole Modes in the Nuclear Collective Model with Dynamical Quadrupole Deformations" in: *Nuclear Spectroscopy and Nuclear Structure. Summary of Reports for Int. Conf. INIS-Ru-347, 1992*, p.486. Printed by "Nauka", S-Petersburg division.

Porodzinskij Yu.V., Sukhovitskij E.Sh. "Using the Real Nuclear Hamiltonian for Analysis of Nucleon Scattering by Nonaxial Deformed even-even Nuclei", *ibid.*

Porodzinskij Yu.V., Sukhovitskij E.Sh. "Realistic Hamiltonian with Allowance of Dynamic Octupole Deformations for Analysis of Neutron Scattering on ^{232}Th and ^{238}U ", submitted to the Int. Conf. on Nucl. Data for Sci. and Tech., 9-13 May, 1994, Gatlinburg, Tennessee, USA.

Klepatskij A.B. "Consistent Analysis and Evaluation of Prompt Fission Neutron and Gamma-ray Spectra and Multiplicities", submitted to the Int. Conf. on Nucl. Data for Sci. and Tech., 9-13 May, 1994, Gatlinburg, Tennessee, USA.

Morogovskij G.B. "The Evaluated Neutron Cross Sections of ^{234}U in Thermal Energy Region", submitted to the Int. Conf. on Nucl. Data for Sci. and Tech., 9-13 May, 1994, Gatlinburg, Tennessee, USA.

II WORK RECENTLY COMPLETED

Near-threshold behaviour of $^{239}\text{Pu}(n,2n)$ reaction cross section is interpreted within a statistical model.

Evaluation of ^{234}U thermal cross sections.

Consistent analysis of nu-bar and prompt fission neutron spectra within Madland-Nix model for minor actinides.

III WORK IN PROGRESS

Statistical model analysis of $(n,2n)$ reaction data near-threshold behaviour for Z-even, N-odd actinides.

Evaluation of actinide $\nu(E)$ and spectra for neutrons and gammas.

Investigation of incorporating symmetric dynamic octupole deformations in case of soft to quadrupole deformations nuclide. The fitting of lowest negative parity bands with consequent analysis of respective excitation functions in a coupled channel approach.

IV WORK PLANNED FOR FUTURE

The optical potential for neutron energies up to 200 MeV

An interpretation of systematic dependence of measured neutron-induced fission cross sections of actinides on fissility in the range 60-200 MeV.

Evaluation of actinide $\nu(E)$ and spectra for neutrons and gammas above 20 MeV.

Evaluation of neutron data for minor actinides.

V WORK ON CODES

See above items III, IV.

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1. RECENT PUBLICATIONS

- T.Jordanov and A.A.Lukyanov, "Analytical Model of Neutron Cross Sections in the Unresolved Energy Region", in print *Bulg. J.Phys.*
- G.Georgiev ...,T.Madjarski, N.Janeva, "Determination of ^{147}Sm and ^{148}Sm Resonance Parameters", in print: *Nuclear Physics A*

2. WORK RECENTLY COMPLETED AND IN PROGRESS

- N.Koyumdjieva, "A Method for Calculation of the Neutron Constants by Using of the Periodical Cross Sections Structure", to be published
- N.Koyumdjieva, A.A Lukyanov and N.Janeva, "Characteristic Functions in the Statistical R-Matrix Theory", to be published
- I.Sirakov and N.Janeva, "Validation of ^{235}U and ^{239}Pu Resonance parameters of ENDF/B-VI "
- I.Sirakov, A.A.Lukyanov and N.Janeva, "Transformation of Reich-Moore parameters of fissile nuclei in ENDF/B-VI to S-matrix ones (Kapur-Peierls parameters at a given energy for calculation of Doppler broadening and Adler-Adler parameters in the corresponding energy ranges for the more convenient Adler-Adler formalism).

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1. Evaluation of Neutron Data for Fe-56 (Zhao Zhixiang, CNDC)

The evaluation includes cross-sections, angular distributions, double differential cross-section for particles, recoils and γ -rays produced in the reactions. The uncertainty files for cross-sections, angular distributions and double differential cross-sections are completely given.

2. The Evaluation of Neutron Data for Hg, Tl, Lu, Ga, Cl (Liu Tingjin, CNDC)

The Evaluation of neutron data for Hg, Tl, Lu, Ga, Cl have been finished in the Chinese Nuclear Data Coordination Network. The neutron cross-section, differential cross-section and double differential cross-section data are included in the data files.

3. The intercomparison of Fe, Cr, Ni Data from CENDL-2, BROND-2, ENDF/B-6 and JENDL-3 (Liu Tingjin, CNDC)

The neutron cross-section, angular and energy distribution data of Fe, Cr, Ni have been plotted and intercompared. Some discrepancies in the cross-sections and problems in the total cross-sections and energy spectra have been found.

4. Codes FMT, CUNF and GUNF (Zhang Jingshang, CNDC)

Based on the unified Hauser-Feshbach and exciton model, the FMT code for fissile materials induced by neutron has been developed. The CUNF code for calculating the data of charged particles (p,d,t, He-3,alpha) induced nuclear reactions and GUNF code for photo-reactions have also been developed. All of these codes FMT, CUNF and GUNF are the new version of the UNF code. The incident energies are up to 20 MeV for FMT, 30 MeV for CUNF and GUNF.

5. DDCS Program (Shen Qingbiao, CNDC)

DDCS is a program for calculating the neutron or charged particles (p,d,t,He-3,alpha) induced reactions of medium-heavy nuclei in the incident energy range up to 50 MeV, including 5 emission processes. It is constructed within the framework of optical model, generalized master equation of the excitation model and evaporation model. The double differential cross-sections, various cross-sections and spectra can be calculated with the program.

6. Channel Theory of Fission with Diffusive Dynamics (Wang Shunuan, CNDC)

The channel theory of fission with diffusive dynamics is proposed based on Bohr channel theory of fission and Fokker-Planck equation. The code CFD is just on the way to calculate the cross-section and neutron spectrum for fission nuclei in 3-20 MeV range.

7. Code IHENRKS (Lu Zhogdao, CNDC)

IHENRKS is the improved QMD. We try to use it to study the mechanism of intermediate and high energy nuclear reaction and apply it for calculating intermediate and high energy nuclear data. The code is in progress.

Fission yield evaluation in China

Wang Dao

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The fission yields of 87' version is presently being revised and updated.

A complete statement of uncertainties in data is given by the covariance matrix, of which the diagonal elements are the variances of uncertainties, and the off-diagonal elements describe the correlations among the data. A complete covariance matrix is useful in estimating the best value and the reasonable uncertainty. As an improvement to the traditional evaluation method, the covariance method has been used¹.

Reference values are the base point of evaluated experimental data, and are used widely, which involve in (1) the whole set of data in U^{235} thermal fission, and (2) all the fission yields concerning the fission products that generally are taken as reference yields (AFFIX).

Reference yields are also used as monitors in some diagnostic measurements, such as in nuclear safeguards research, fuel burn-up analysis, etc.

At present, the evaluation related to reference yields is in progress.

1. Wang Dao, Covariances in Fission Yield Evaluation for CENDL, the Proceedings of NEANSC Specialists' Meeting on Fission Product Nuclear Data, Japan, 22th - 24th May 1992.

AFFIX

Fission products whose fission yields are taken as reference yields^①

Kr83g	stable	Kr85g	10.72 y
Kr85m	4.480 h	Kr86	stable
Kr87	76.3 m	Kr88	2.84 h
Sr89	50.55 d	Sr90	28.6 y
Y 91g	58.51 d	Zr95	64.02 d
Zr96	stable	Nb95g	34.97 d
Nb95m	3.61 d	Mo95	stable
Mo99	66.0 h	Mo100	stable
Ru101	stable	Ru102	stable
Ru103	39.26 d	Ru106	371.63 d
Rh105g	35.36 h	Rh106g	29.80 s
Ag111g	7.45 d	Cd115g	53.46 h
Cd115m	44.6 d	Sb125	2.73 y
Te132	78.2 h	I 131	8.04 d
I 135	6.61 h	Xe131g	stable
Xe131m	11.9 d	Xe132	stable
Xe133g	5.245 d	Xe133m	2.188 d
Xe134g	stable	Xe135g	9.09 h
Xe135m	15.29 m	Xe136	stable
Xe137	3.818 m	Xe138	14.08 m
Cs133	stable	Cs134g	2.062 y
Cs136	13.16 d	Cs137	30.17 y
Ba140	12.746 d	La140	40.272 h
Ce141	32.501 d	Ce143	33.0 h
Ce144	284.4 d	Pr141	stable
Pr144g	17.28 m	Nd143	stable
Nd144	stable	Nd145	stable
Nd146	stable	Nd147	10.98 d
Nd148	stable	Pm147	2.6234 y
Pm148g	5.370 d	Pm148m	41.29 d
Pm149	53.08 h	Pm151	28.40 h
Sm149	stable	Sm151	90 y
Sm153	46.7 h	Eu153	stable
Eu154g	8.8 y	Eu155	4.96 y
Eu156	15.19 d	Tb161	6.90 d

^①For the nuclides without suffix g or m, they have no isomers

PROGRESS ON CHINESE EVALUATED NUCLEAR PARAMETERS LIBRARY(CENPL)(III)*

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Yu Ziqiang Zuo Yixin

(NANKAI UNIVERSITY)

The setting up work of each sub-library of CENPL have got some new progresses at the past period. They are introduced as following.

1. Atomic masses and characteristic constants for nuclear ground states sub-library(CENPL-MCC).

We added the function of retrieving for natural isotopic composition in the management-retrieval code system, i.e. user can retrieve abundance, atomic mass, mass excess, binding energy and spin, parity of ground state of all stable isotopes for this element isotope. The retrieval system can also retrieve the separation energies of neutron, proton, deuteron, triton, ^3He , α , $2n$ and $2p$ and the decay energy of β^+ and β^- for the isotopes.

Neutron reaction retrieving system of this sub-library has been finished. With this retrieval system user can get, for a target, the Q value and the threshold energy E_{th} of each reaction channel included in up to the third reaction process. According to retrieved E_{th} , user might choose a code from four type popular fast neutron codes for model computations, and retrieve the all masses required in the input data file of the chosen code.

2. Discrete level schemes and branch ratios of gamma decay sub-library(CENPL-DLS).

The data of DLS sub-library come from the Evaluated Nuclear Structure Data File which is a computer file of evaluated experimental nuclear structure data maintained by the National Nuclear Data Center, Brookhaven National Laboratory. We have decided the data format in the DLS data file. For each level we give its order number, energy, spin, parity and half-life. For γ decay we give the order number of the final state level, the relative transition branch ratio and the multipolarity of γ radiation. We have finished the code of transforming format from ENSDF to DLS and provided examples. We are completing the code and setting up the DLS data file.

3. Level density parameters sub-library(CENPL-LDP).

By using the moment method, likelihood method and a new method used to give Bayesian estimation by making provided by Wigner distribution. We have re-evaluated D_0 at the neutron binding energy and obtained the neutron resonance strength function S_0 . Based on the work we set up the file of 'Four kinds of experimental data related to level density'(1993 version). This file contains the values of D_0 and the cumulative number of levels N_0 for 332 nuclei in the range ^{17}O to ^{254}Es , the radiative capture width GW at B_n for 208 nuclei from ^{33}S to ^{280}Bk and the neutron strength function S_0 for 202 nuclei from ^{24}Na to ^{254}Es .

4. Giant dipole resonance parameters for γ -ray strength function sub-library(CENPL-GDP).

We have improved and perfected the data file and the management-retrieval system further, which could provide for using ⁽¹⁾.

5. Fission barrier parameters sub-library(CENPL-FBP).

This sub-library was improved and perfected further, which could be used ⁽²⁾

6. Optical model parameters sub-library(CENPL-OMP).

A data file of global optical model parameters of neutron and charged particle is being built. This file dose not only retrieve OMP and user can also get the information and the comment on the potential.

The data file of optimized OMP from CENDL-1,2 has been set up with dBASE method.

Our following work will to expend the data file and decide the

management—retrieval scheme.

Ms. Zhang Limin, Mrs. Jin Yongli Sun Zhenjun, Zhao Fengquan (CNDC).
Drs. Ma Gonggui(Sichuan Univ.), Yao LiShan(Shaanxi Normal Univ.), Zhu
Yaoyin(Jilin Univ.) et al. take part in partial above works and related activities.

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der contract No.7431 / RB.

REFERENCES

- [1]. Zuo Yixin et al., to be published.
- [2]. Zhang Limin et al., to be published.

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Work recently completed

1. New Resonance Parameters and Covariances for ^{56}Fe

The resonance parameters for $^{56}\text{Fe}+n$ were updated for the files JEF and EFF. The new evaluation up to the first inelastic threshold at 862 keV is based mainly on the ORNL transmission analysis of Perey et al. (1990) for level energies and neutron widths, on capture data by d Allen et al. (1976), Käppeler et al. (1983), Wisshak et al. (1984) and Corvi et al. (1991) for capture widths, and on level statistics for assignment of unknown spins and partial widths. Covariances between neutron and capture widths were derived from transmission dip and capture peak areas as described in Fröhner (1993).

2. Study of the Cross Section Fluctuations for ^{56}Fe

New high-resolution transmission data measured at Geel (Berthold et al. 1992) show that significant resonance structure persists in the ^{56}Fe cross sections to energies well above 5 MeV. The fluctuations of the Geel total cross section data were separated from the average (optical-model) behaviour up to 7 MeV. They are being used to prepare fluctuating partial cross sections for studies of the effect on shielding and self-shielded activation in the context of the ITER project (cf. Fröhner 1993).

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Work in progress

New Resonance Parameters and Covariances for ^{58}Ni , ^{60}Ni

A similar update of the resonance parameters for ^{58}Ni and ^{60}Ni as described under 1. above for ^{56}Fe is under way.

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1. MODELS AND CODES

i) The multistep-compound theory of Nishioka-Verbaarshot-Weidenmueller has been coded and the results have been analysed and discussed against experimental information.

ii) Particle capture mechanisms (direct, semidirect and preequilibrium) have been analysed and capture via multistep compound mechanism according to Nishioka-Verbaarshot-Weidenmuller has been included as well. Comparison between theory and experiment has been critically examined.

iii) Nuclear photoreactions

Within the framework of the extended interacting boson model, including p-boson excitations, calculations of photon absorption cross sections in the energy region of the isovector giant dipole resonances have been performed for W isotopes. Moreover, a detailed analysis of the (γ , n) cross section was performed for Xe isotopes, of interest in the production of radioactive I nuclides, for biomedical use and the corresponding data for ^{124}Xe were calculated within the model approximation.

iv) Capture gamma-ray emission

The Valence Model has been tested against a new set of experimental data on the $n + ^{53}\text{Cr}$ reaction. The results of the analysis show that in addition to the Valence capture process, a residual statistical component and possibly a doorway mechanisms are necessary for the description of gamma-ray emission probabilities.

v) Advances in nuclear spectroscopy and level density studies.

The previous nuclear structure investigations by the IBM model on discrete levels were extended to the case of odd-odd nuclei, namely $^{98,100}\text{Tc}$, taking into account recent measurements. To this end, a computing code was developed where one unpaired neutron and one unpaired proton are coupled to an IBM-2 core by means of a suitable fermion-boson interaction. Relevant results for $^{98,100}\text{Tc}$ were obtained.

Decay properties of mixed-symmetry collective bands in vibrational nuclei were investigated and the main conclusion was that mixed-symmetry β -vibrational bands could be identified only by means of a joined comparison of E0, E2 and M1 transition intensities. Even-even Cadmium isotopes as possible candidates for the identification of mixed-symmetry collective bands were proposed and further experiments suggested in order to draw definite conclusion (Cooperation with INFN-Florence).

The problem of inclusion of collective degrees of freedom in the description of nuclear level density has been investigated. The Interacting Boson Model (IBM) has been applied for the evaluation of the collective enhancement of nuclear level density for nuclei having different geometrical shapes and corresponding to different dynamical symmetries of the IBM. In the same field, a systematics of nuclear level density parameters have been constructed using the most recent compilations of experimental information on average spacings of neutron resonances and on other nuclear structure properties (Cooperation with JAERI, Nuclear Data Center).

Then collective enhancement factor of level densities for transitional nuclei in the mass regions around $A=150$ and 190 have been estimated and numerical results have been obtained for Sm and Os isotope chains.

2. EVALUATION

i) The reevaluation of Mo isotopes for EFF-2 has been completed. A critical intercomparison of previous evaluations has been performed. Gamma-ray spectra and double differential cross sections for particle emission were included in ENDF/B-6 format.

ii) A revised evaluation for Fe-56 for EFF-2 has been brought up, including gamma-ray emission spectra and double differential particle emission cross sections in ENDF/B-6 format.

iii) Activation cross sections.

In the frame of the IAEA CRP on Long-Lived Activation Data, a preliminary analysis of nuclear structure information about nuclei of practical importance has been carried out.

Numerical calculations of level spectra and densities have been also performed within the framework of the interacting boson-fermion model.

3. DATA PROCESSING

In this framework the following libraries are underway or have been completed:

i) GEF2: this P_5 library for fusion neutronics calculations is based upon the 175 neutron, 42 photon VITAMIN-J group structure with the standard weighting function. It includes 93 materials, most from EFF-2 basic data, at 3 temperatures and 6 dilution cross section values; 10 thermal groups are provided below 3 eV. Neutron cross sections and diffusion matrices, photon and gas production, kerma and DPA are given; in a separate file a 42 group photon interaction P_8 library from EPDL-90 has been prepared too. NJOY 91.38 version has been used to process all the data. The library is being produced both in GENDF and in MATXS format and is 90% complete. This work has the financial support of the European Programme for Fusion NET.

ii) a parallel library of pointwise data for the Montecarlo code MCNP is being prepared. It includes all EFF-2 materials. A modified version of the NJOY 91.38 ACER module is used to process the data and to try to account for photon production and DDX data; the problem is that ACER accepts only (and with some limitations) the Kalbach-Mann formalism for double differential data in MF=6; for this reason the status of the library is at 70%. This work has the financial support of the European Programme for Fusion NET. (Cooperation with ENEA Frascati).

iii) COVNET: a group library of covariance data from EFF-2. The 24 neutron group DOSCOV structure has been adopted first, since the group boundaries are a subset of VITAMIN-J group structure; later on from interactions with the users, it has been acknowledged the poor structure of the group scheme in the energy range of interest for fusion problems, so as the library has been recalculated over the 175 group VITAMIN-J standard set. The libraries include 18 materials - the ones with error data in EFF-2.3, i.e.: H-1, Li-6, C, V, Cr-52, Mn-55, Fe-56, Ni-58, Ni-60, Ni-61, Ni-62, Ni-64, Cu-63, Cu-65, Nb-93, Re-185, Re-186 - processed by the NJOY 91.38 module ERRORR and COVR and are written in BOXER format; graphs of covariance matrices have been produced by the graphics facilities of NJOY. The library is complete and in use. The work has the financial support of the European Programme for Fusion NET. (Cooperation with ENEA Frascati).

iv) IRDF-90 have been collapsed into 175 group VITAMIN-J in order to provide activation and dosimetry cross sections to carry away computations in connection with COVNET; for this purpose NJOY has been used by considering IRDF (which is in form of histograms) as a pointwise file with interpolation code JNT =1; the discrepancies at the group boundaries of the coarser grid are compensated by the very high resolution (640 groups SAND-II scheme whit flat weighting) of the fine grid of the source. With the same assumption, data have been generated by NJOY modules for the main (28) dosimetric reactions covariance.

v) All iron isotopes from EFF 2 have been processed into a from suitable for sensitivity analysis and made available in the frame of the european collaboration for fusion.

vi) In the framework of the ENEA/CEA Cooperation for Future Reactors the processing of structural materials from JEF-2.2 to produce a test library for ECCO has been completed. The task includes Cr, Fe, Ni, Mn, Mo, Zr processed into standard 1968 energy groups in GENDF format at 4 temperatures, infinite dilution and with Legendre angular momentum $l=5$. The file was subsequently processed by CALENDF and CRECCO to produce the final library including self-shielding.

A library of 41 shielding materials from JEF 2.2 has also been prepared into the VITAMIN-J scheme at 293.16K, infinite dilution, $l=5$. The completion with damage data (kerma and photon production) has been performed too together with the processing of some fission products into XMAS group scheme.

(Cooperation with ENEA Unit for Advanced Fission Reactors).

vii) A group library for the Montecarlo code FLUKA has been prepared on a 72 neutron 22 photon group structure with VITAMIN-J averaging function for neutronics calculations on the detectors of the LHC machine at CERN, Geneve. The library is based upon JEF-2.1, ENDF/B-VI and LLNL, has been processed by NJOY version 91.38 and includes 70 materials at 2 temperatures and infinite dilution: neutron data, photon production, kerma and reaction cross sections are given. The format is particular of FLUKA: a DTF version also existes to circulate among the users; the library is in use.

A new version of the library is underway based upon the VITAMIN-J structure. It uses as source data JEF 2.2 and ENDF/B-VI and it differs from the previous one mainly in that it accounts for the resonance shelf shielding. Furthermore, beside the data type of version 1, it includes matrices for the diffusion of secondary charged particles when data are available in the source files; separate elastic and non-elastic neutron diffusion matrices are also given. The adopted format is MATXS: problem oriented DTF version to input to FLUKA is planned to be prepared by TRANSX 2.9 version. The library is at 50%; the list of the included materials is still not complete but its number ranges between 80 and 120. (Cooperation with INFN-Milan).

4. NUCLEAR DATA VALIDATION

i) Work completed.

A detailed ENEA report was written on the validation of the JEF-2 iron cross sections, on the (H₂O/Fe) PCA-REPLICA neutron shielding benchmark. The results presented include a comparison with those of a previous JEF-1 natural iron validation and are based on a conclusive paper presented at the JEF Working Group Meetings in June 1992 at the NEA Data Bank.

An analogous work on the ENDF/B VI iron validation on the same benchmark, was completed. It will be presented at the 8th International Conference on Reactor Shielding in Arlington (Texas - USA) on April 1994. It is recalled that the (H₂O/Fe) PCA-REPLICA (UKAEA-Winfrith) low-flux shielding experiment reproduces the ex-core radial geometry of a PWR and is closely related to LWR safety. In particular this benchmark permits to test the accuracy of the calculated neutron exposure parameters in a reactor pressure vessel simulator.

ii) Work in Progress

New SN validation calculations on PCA-REPLICA are in progress to test the JENDL-3 iron files.

5. NUCLEAR DATA FOR RADIATION DAMAGE ASSESSMENT

i) Recognizing that the neutron damage in crystalline materials depends on the creation and evolution of displacement cascades produced by the primary-knock on-atoms (PKA), the HEATR module of the NJOY nuclear data processing system (for estimating the damage energy due to neutron irradiation using data in the ENDF/B format) has been modified in order to calculate the PKA spectrum for a single nuclide, using cross sections and distributions from the ENDF/B files.

As a first example, in particular, the PKA spectrum for Fe-56 was obtained for monoenergetic neutrons.

6. PROBLEM DEPENDENT LIBRARIES FOR THE FISSION REACTOR DECOMMISSIONING:

i) The time-dependent cross sections for ORIGEN-S Libraries of the various types of fuel assemblies with complex irradiation history have been prepared to be used in calculating the Radionuclide Inventories of the spent fuel (before and after fuel reprocessing) discharged from the TRINO light-water reactor.

ii) The spent-fuel decay Libraries for the neutron (spontaneous fission, alpha-n and total-n) and gamma radiation source calculation associated to MAGNOX vetrified residue fuel from LATINA reactor have been prepared.

7. PROBLEM DEPENDENT LIBRARIES FOR SAFETY STUDIES ON FUSION REACTORS (NET/ITER Project and CEE SEAFP Project)

i) The neutron and decay "working" libraries to perform shielding analysis and activation calculations for the AISI 316L First Wall with Be, B₄C, W or Graphite coating materials have been produced.

ii) The activation "working" libraries to estimate the process source terms due to the activated corrosion products related to the Inboard and Outboard First Wall AISI 316L cooling pipes and to the TZM cooling pipes of the Divertor Plates have been generated.

iii) The transport and activation "working" libraries for breeder and multiplier materials containing Hafnium impurities to estimate the impact of Hafnium content on nuclear (TBR) and safety properties have been generated.

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- Publications : 1) S.B. Garg; Analysis of (n,2n) cross-sections of natural zirconium in the frame work of GDH model with various level density recipes, Paper presented at the Nuclear Physics Symp., Calicut, India (1993)
- 2) S.B. Garg; Multineutron emission Cross-sections of Bi-209, Paper presented at the Nuclear Physics Symp., Calicut, India (1993).

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Publications

- 1) H. Kitazawa, M. Igashira, Y. Achiha, N. Mukai, F. Uesawa, T. Andoh and S. Shibata: "Core Polarization in the 203 keV $p_{1/2}$ -Wave Neutron Resonance Capture by ^{32}S ," *Nucl. Phys.*, **A536**, 109 (1992)
Primary E1 transitions from the 230 keV $p_{1/2}$ -wave resonance of ^{32}S were found to be in a marked discrepancy with predictions of the Lane-Mughabghab valence-capture model. The discrepancy was removed by a particle-vibrator coupling model, in which an explicit account was taken of the core polarization due to quadruple and octuple one-phonon excitation in the resonance state.
- 2) H. Kitazawa, M. Igashira, M. Shimizu, K. Muto, T. Oda, Y. Achiha, Y.-H. Lee and N. Mukai: "Electric and Magnetic Dipole Transitions from Broad s-Wave Neutron Resonance in Even-Even sd-Shell Nuclei," *Phys. Rev.*, **46**, 2364 (1992).
Primary E1 transitions from the broad s-wave resonances at 658 keV in ^{24}Mg , at 180 keV in ^{28}Si , and 1-3 keV in ^{32}S were well explained by the Lane-Mughabghab valence-capture model. Moreover, it was shown that the enhancement of primary M1 transitions results from excitation of isovector M1 states in the core nucleus.
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Evaluated neutron nuclear data libraries of fission product nuclides, JENDL-3, JEF-2 and ENDF/B-VI, are reviewed. For the inelastic scattering cross sections, the activities of Subgroup 10 in the NEANSC International Evaluation Cooperation are introduced.
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Evaluation of resonance parameters was made on experimental resonance parameters deduced by experimenters. Computer programs for the evaluation are described.
- 6) M. Igashira, H. Kitazawa and K. Takaura: "Valence-Neutron Capture in the 434 keV $p_{3/2}$ -Wave Resonance of ^{16}O ," *Nucl. Phys.*, **A536**, 285 (1992).
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Evaluated quantities are the total, elastic, total reaction, particle production and isotope production cross sections, and double differential particle emission spectra for the neutron and protons up to 1 GeV.

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An outline of JENDL actinide file and high energy files is described by showing results of nuclear data evaluation of ^{237}U , ^{236}Np and ^{238}Np up to 20 MeV and those of ^{27}Al , Pb and ^{209}Pb up to 1 GeV.

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Experimental data used for evaluation of resonance parameters which were evaluated by H. Derrien and G. de Saussure (*Nucl. Sci. Eng.*, 106, 415) and adopted in ENDF/B-VI were re-normalized to the results of recent measurement of the ^{241}Pu fission cross section in the energy range from 0.002 to 20 eV. The resonance parameters were re-analyzed, resulting in a decrease of the fission cross section by about 3 % on average.

- 19) H. Kitazawa and M. Igashira: "Electromagnetic Transitions from Broad Neutron Resonance in Nuclei with $A < 40$ and Resonance Structure," *Proc. 8th Int. Symp. on Capture Gamma-Ray Spectroscopy and Related Topics, Fribourg (1993)*.

The paper reviews new findings obtained from our studies on primary electromagnetic transitions from broad s-, p-, d-wave resonances in p-shell and sd-shell nuclei. Those findings include strong p \rightarrow s and s \rightarrow p valence transitions, retardation of p \rightarrow d and d \rightarrow p single-particle transitions, and vibrational, rotational and isovector spin-dipole core polarization of resonance state.

Work recently completed

- 1) H.Kitazawa, M. Igashira, S. Shibata, K. Tanaka, H. Takakuwa and K. Masuda: "Retardation of Single-Particle E1 Transitions from the 622 keV Broad d-Wave Neutron Resonance in

⁹Be," submitted to *Nucl. Phys. A*.

Strong primary E1 transitions from the 622 keV broad d-wave resonances in ⁹Be were found to be appreciably hindered, as compared with the Lane–Mughabghab valence-capture model predictions. This noticeable E1 retardation can be explained by assuming the coupling between the d-state neutron single-particle motion and the E1 giant-resonance excitation of the target nucleus.

- 2) A. Mengoni and Y. Nakajima: "Fermi-gas Model Parametrization of Nuclear Level Density," to be published in *J. Nucl. Sci. Technol.*

Authors furnished a new parametrization of Fermi-gas model description of nuclear level densities at the neutron binding energy. The model adopted is the standard Fermi-gas model with pairing and shell-effect corrections. The procedure for evaluation of level density parameters was applied to a data-base of 217 nuclides in a mass range from 41 to 253. A global systematics parametrization was derived.

- 3) H. Derrien: "R-Matrix Analysis of Neutron Effective Total Cross Section, Fission Cross Section and Capture Cross Section of ²³³U in the Energy Range from Thermal to 150 eV," to be published in *J. Nucl. Sci. Technol.*

Reich-Moore resonance parameters for ²³³U were obtained by fitting selected experimental data in the energy range from thermal to 150 eV by means of SAMMY.

Work in Progress

- 1) Evaluation of neutron cross sections of ¹²C up to 50 MeV

S. Chiba, T. Fukahori, Y. Watanabe and Y. Koyama

Neutron cross sections of ¹²C have been evaluated from 20 to 50 MeV. The total cross section and associated covariance matrix were obtained from the least-squares analysis of available data. Other cross sections have been obtained with the aid of (microscopic) optical model and DWBA calculations. The double-differential cross sections of various particles, including recoil atoms, have been calculated based on the Monte-Carlo method.

- 2) Evaluation of neutron cross sections of hydrogen from 20 MeV to 1 GeV

S. Chiba, S. Morioka and T. Fukahori

Neutron cross sections of ¹H have been evaluated from 20 MeV to 1 GeV. The total cross section, elastic and inelastic scattering cross sections and their angular distributions have been evaluated based on the least-squares method with covariance information and also on the phase-shift data of Arndt et al. The covariance matrix of evaluated total cross section has been also obtained. The capture cross section was calculated from the inverse reaction cross section of Feshbach-Schwinger theory.

- 3) QMD calculation of nucleon-nucleus reaction cross sections

S. Chiba

The Quantum Molecular Dynamics (QMD) has been applied in calculation of nucleon induced reactions on ¹²C and ²⁷Al. Preliminary results showed that QMD gives good description of the nucleon-emission channel, while emission of clusters (such as α) were underpredicted considerably. This result implies different mechanisms of cluster emission in nucleon induced and heavy ion induced reactions.

Work about Codes

- 1) T. Fukahori, S. Chiba, H. Takada, N. Kishida, Y. Watanabe and N. Yamamuro: "Benchmark Calculations of Theoretical Calculation Codes for Nuclear Data Evaluation in the Intermediate Energy Region," *Proc. 1992 Symposium on Nuclear Data, Tokai, Nov. 26-27, 1992, JAERI-M 93-046, p.57 (1993)*.
Benchmark calculations of isotope production cross sections in the intermediate energy ranges of neutron and protons were made by using SINCROS-II, ALICE-F, EXIFON, MCEXCITON, METC-3STEP and NUCLEUS.
- 2) T. Nakagawa and T. Fukahori: "Integrated Nuclear Data Evaluation System," *ibid.*, p.100 (1993).
Integrated Nuclear Data Evaluation System (INDES) is under development. INDES provides information on nuclear data to users and creates JCL and input data of theoretical calculation codes. An outline of INDES is explained.
- 3) A. Mengoni and Y. Nakajima: "HERMES: A Personal-Computer Program for Calculation of the Fermi-Gas Model Parameters of Nuclear Level Density," *JAERI-M 93-177 (1993)*.
HERMES provides the quantities needed in nuclear level density calculation. The applied model is the standard Fermi Gas Model in which pairing correlations and shell effects are taken into account. The effects of additional nuclear structure properties are also considered. Using HERMES, a level density parameter systematics has been constructed for mass range from 41 to 253.

Work planned for the Near Future

- 1) JENDL-3 revision 2 (JENDL-3.2)
Nuclear Data Center and Japanese Nuclear Data Committee
Revision work of JENDL-3 to JENDL-3.2 is being performed. JENDL-3.2 will be contained data for 340 nuclides. The data for about half of them will be modified or new evaluation. JENDL-3.2 will be released at the end of March 1994.
- 2) Evaluation of JENDL Fusion File
S. Chiba, B. Yu, T. Fukahori and K. Kosako
Evaluation of JENDL Fusion File will be completed in near future in order to improve the double-differential cross section (DDX) of JENDL-3. DDX of n, p, d, t, ^3He and α are calculated by systematics of Kumabe et al. and Kalbach. JENDL Fusion File will contain the data of Li, Be, B, C, N, O, F, Al, Si, Ca, V, Ti, Cr, Mn, Fe, Co, Ni, Cu, Ge, As, Zr, Nb, Mo, Sn, Sb, W, Pb and Bi.

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H.A.J. van der Kamp, A.J. Koning, D. Nierop

1. RECENT PUBLICATIONS AND REPORTS

Low energy data:

- [1] J. Kopecky, M. Uhl and R.E. Chrien, Radiative Strength in the Compound Nucleus Gd-157, Phys. Rev. C47(1993) 312.
- [2] M. Avrigeanu, P.E. Hodgson and A.J. Koning, Semiclassical and Quantum Mechanical Pre-equilibrium Neutron Emission, J. Phys. G., 19(1993) 745.
- [3] J. Kopecky and D. Nierop, Status of Cr-52, Fe-56 and Ni-58,60 Data; Graphical Intercomparison with Recent Libraries in VITAMIN-J Structure, EFF-Doc-202 (EFF Newsletter - 6).
- [4] J. Kopecky and H. Gruppelaar, Status of the European Fusion File (Revision 2.3), EFF-Doc-203 (EFF Newsletter - 5).
- [5] J. Kopecky, H.A.J. van der Kamp and H.Gruppelaar, Revision of the PB-0 evaluation, EFF-Doc-204 (EFF Newsletter - 7).
- [6] J. Kopecky and D. Nierop, Graphical Intercomparison of Fe Data from EFF-1 and EFF-2.3 Libraries in VITAMIN-J Structure, EFF-Doc-207 (EFF Newsletter - 8).
- [7] J. Kopecky, H.Gruppelaar and D. Nierop, The European Activation File EAF-4, - Progress Report -, EAF-Doc-002.
- [8] H. Gruppelaar and J. Kopecky, Overview of EFF/EAF Projects, EFF-Doc-237.
- [9] J. Kopecky and H. Gruppelaar, Status of the European Fusion File (Revision 2.4), EFF-Doc-241 (EFF Newsletter - 7).
- [10] J. Kopecky, H. Gruppelaar and D. Nierop, Status of the European Fusion File (Point-wise Revision 2.4), EFF-Doc-242 (EFF Newsletter - 8).

[11] J. Kopecky, Intercomparison EFF-2 and FENDL-1 libraries, EFF-Doc-243.

High energy data:

[12] A.J. Koning, Review of High Energy Data and Model Codes for Accelerator-based Transmutation, ECN-C--93-005 (1993).

[13] A.J. Koning, Requirements for an Evaluated Nuclear Data File for Accelerator-based Transmutation, ECN-C--93-041 (1993).

[14] A.J. Koning and H. Gruppelaar, Nuclear Data Evaluation for Accelerator-based Transmutation of Radioactive Waste, ECN-RX--93-069 (1993).

[15] R. Benetti, A.J. Koning, J.M. Akkermans and P.E. Hodgson, The Feshbach-Kerman-Koonin Multistep Direct Reaction Theory, Physics Reports, in press, 1994.

2. WORK RECENTLY COMPLETED (GENERAL)

- See above-mentioned publications and reports.
- Completion of the point-wise revision EFF-2.4 of the European Fusion File (to be released in January 1994).
- Update of activation cross-section file EAF-3 (released in September 1993).
- Revision of the ECN Pb-0 evaluation (see [5]).
- Completion of code system for Multi-Step Direct Reactions.

The main activity of the group lies in the EFF and EAF projects, which are part of the European Fusion Technology Programme of the European Community. The following laboratories are contractors in these projects: CEA (Saclay), ECN (Petten), ENEA (Bologna and Frascati), KfK (Karlsruhe) and AEA (Culham). Moreover, JRC IRMM (Geel) is involved as an EC research institute. The projects are directed by the NET team at Garching and by EC in Brussels. Other European laboratories are also involved: the University in Birmingham and IRK (Vienna). Furthermore, technical support is received from the NEA Data Bank. At present this programme has become a part of the ITER project through the EC Home Team at Garching.

Several studies on data needs for accelerator-based transmutation of radioactive waste and the associated aspects of future intermediate energy data evaluation activities have been performed. ECN is involved in the coordination of the subgroup on Intermediate Energy Nuclear Data, formed by the Nuclear Science Committee of the NEA.

3. WORK IN PROGRESS

- Improvements of EFF point-wise library, EFF-2.5 revision to be released as EFF-3 at the end of 1994.
- Extension of the activation file, compilation of the European Activation File (EAF-4) to be released in 1994.
- Study of photon production cross-sections and spectra calculations for deformed targets.
- Study of available experimental data and model codes for high energy reactions.

4. FUTURE PLANS

- Update of fission-product cross-sections.
- Work for EFF-2 (European Fusion File) and EAF (European Activation File) in the frame of the EC and ITER projects.
- Extension of pre-equilibrium process to higher energies.
- Update of working libraries for nuclear transmutation studies of actinides and fission-products.
- Evaluation of intermediate (>20 MeV) data files.
- Completion of evaluation code for intermediate energies.
- Further studies on nuclear data needs for accelerator-based transmutation of radioactive waste.

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Names: **A. Marcinkowski and D. Kielan**

Activity: Investigation of cross sections for (n,p) reaction on chains of target isotopes. Activation measurements and model calculations of cross sections.

Facilities: 3 MeV Van de Graaff accelerator, 80 cm³ Ge(Li) spectrometer, HP Apollo 720 work station.

Work in progress: Measurements of excitation functions for ^{64,66,67,68}Zn(n,p) and ^{52,53}Cr(n,p) reactions for incident energies from 13.0 MeV to 16.6 MeV. Implementation of the model for gradual absorption, a phenomenon accompanying MSD processes, in calculations of the MSC cross sections. Extended version of EMPIRE for MSC calculations.

Publications: D. Kielan *et al*, Isotopic effect in (n,p) reaction on ruthenium, Nucl. Phys. A559(1993)333;
A. Marcinkowski *et al*, Neutron emission cross sections at low bombarding energies and the novelty in multistep compound reaction model, Nucl. Phys. A561(1993)387.

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I. RECENT PUBLICATIONS

1. M. Avrigeanu, P.E. Hodgson and A.J. Koning: "Semiclassical and quantum mechanical pre-equilibrium neutron emission", *J. Phys. G: Nucl. Part. Phys.* **19**, 745 (1993)
2. V. Avrigeanu, P.E. Hodgson and M. Avrigeanu: "Global optical potentials for emitted alpha particles", *Phys. Rev. C* (in press)
3. M. Avrigeanu and V. Avrigeanu: "Energy-dependent single-particle state density effects in the hybrid model of pre-equilibrium nuclear reactions", *J. Phys. G: Nucl. Part. Phys.* (in press)
4. M. Avrigeanu, V. Avrigeanu and P.E. Hodgson: "The alpha-particle mean field and consistent pre-equilibrium and statistical emission", in: "Proc. Int. Advanced Courses on Frontier Topics in Nuclear Physics, Predeal, Romania, 1993", W. Scheid, A. Sandulescu (Eds.), Plenum, New York, (in press)
5. V. Avrigeanu and A. Harangoza: "Thermonuclear reaction rate uncertainties from nuclear model calculations", *ibid.*

II. WORK IN PROGRESS

1. Realistic particle-hole state density effects in multistep reaction calculations

(M. Avrigeanu, P.E. Hodgson and V. Avrigeanu)

The theory of multistep nuclear reactions¹ is applied in conjunction with realistic particle-hole state densities including advanced Pauli and pairing correction² and energy-dependent single-particle state density. Different energy dependences and values at the Fermi level of the single-particle state density for holes and excited particles³ are considered. The multistep direct (MSD) and multistep compound (MSC) fast neutron induced reactions on 46 – 50Ti and 56Fe isotopes are analyzed by means of the codes MUDIR4 and GAMME5 respectively, while the code STAPRE-H is used for the second-chance particle emission and comparative analysis of semiclassical and quantum-mechanical models. The same parameters for exciton state and nuclear level densities, and optical potentials are used in this respect. This consistent set of statistical model parameters has been used to describe also the fast neutron cross sections for all V, Cr, Mn, Fe, Co and Ni stable isotopes.

[1] H. Feshbach *et al*, *Ann.Phys.(NY)* **125**,429(1980). [2] C. Kalbach, *Z.Phys.* **A332**,157(1989). [3] H. Herman *et al*, *Phys.Rev.C* **40**,2870(1989). [4] R. Bonetti and C. Chiesa: MSD Code, Milano Univ. (unpublished) [5] R. Bonetti and M.B. Chadwick: GAMME Code, Oxford Univ. Report OUNP-91-16.

2. The α -particle mean field and consistent pre-equilibrium and statistical emission.

(V. Avrigeanu, P.E. Hodgson and M. Avrigeanu)

A set of global optical model parameters¹ for α -particles with energies above 80 MeV, extended to lower energies to describe (n, α) reactions, is involved in additional analyses of total and (α ,N) reaction cross sections. The Geometry-Dependent Hybrid model with intranuclear transition rates related to the averaged imaginary optical model potentials² is used for the α -particle pre-equilibrium emission, while the same parameter sets have been involved within the pre-equilibrium and statistical models. Comparison with the available experimental (n, α) reaction cross sections and spectra in the mass range $A \approx 50$ supports the value³ $g_\alpha = (A/10.36) \text{ MeV}^{-1}$ of the α -particle state density at the respective Fermi level⁴, while energy-dependent single-particle state density is used within particle-hole state density formalism (code STAPRE-H93).

[1] M. Nolte *et al*, *Phys.Rev.C* **36**,1312(1987). [2] M. Blann, *Nucl.Phys.* **A213**,570(1973). [3] E. Gadioli *et al*, *Z.Phys.* **A299**,1(1981). [4] W. Scobel *et al*, *Nucl.Phys.* **A287**,301(1977)

3. Compilation of the optical model potentials for α -particles on target nuclei with $A \geq 100$. (M. Avrigeanu and V. Avrigeanu)

Compilation carried on as part of the IAEA/NDS Project for the development of a Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data.

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Recent Publications:

1. E. Běták, P. Obložinský:
PEGAS: Pre-Equilibrium-Equilibrium Gamma-And-Spin Code (PC Version)
Report INDC(SLK)-001, IAEA Vienna 1993
2. S. Cierjacks, P. Obložinský, S. Kelzenberg, B. Rzehorz:
Development of a novel algorithm and production of new data libraries for the treatment of sequential (x,n) reactions in fusion material activation calculations
Fusion Technology (USA) 24 (1993), 277-287
3. F. Cvelbar, E. Běták, A. Likar:
Pre-equilibrium and direct-semi-direct model calculations of proton radiative capture excitation functions
J. Phys. G19 (1993), 1937-1945
4. S. Hlaváč, V. Varga, J. Kliman, L. Dostál, M. Dluhoš:
Cross-section of the $^{16}\text{O}(n,\gamma\alpha)$ reaction at 14.7 MeV
Report INDC(NDS)-273, IAEA Vienna 1993
5. P. Obložinský:
Models for calculations of photoproduction cross-sections and emission spectra in Symp. Nuclear Data Evaluation Method., Brookhaven (USA) 12-16 October 1992, ed. C.L. Dunford, World Sci. Singapore 1993, pp. 458-467

Work Recently Completed and in Progress:

1. E. Běták:
Hard gammas from low-energy heavy-ion collisions

2. M.B. Chadwick, P.G. Young, P. Obložinský, A. Marcinkowski:
Pre-equilibrium spin effects in Feshbach-Kerman-Koonin and exciton models and application to high-spin isomer production.
3. S. Hlaváč, P. Obložinský, L. Dostál, I. Turzo, H. Vonach, A. Pavlik, S. Simakov:
Study of gamma-radiation from interaction of 14.7 MeV neutrons with ^{208}Pb .
4. *Inclusion of discrete γ transitions into the Pre-Equilibrium-Equilibrium Gamma-And-Spin code PEGAS*

I. RECENT PUBLICATIONS

1. Pre-Equilibrium Emission and Statistical Model Parameter Effects on Reaction Cross-Section Calculations. By M. Avrigeanu, V. Avrigeanu and P.E. Hodgson. Progress Report of Department of Heavy Ion Physics, Institute of Physics, Bucharest 1990-1991, p.26.
2. Comparative Semi-Classical and Quantum-Mechanical Nucleon Pre-Equilibrium Emission Calculations. By M. Avrigeanu and P.E. Hodgson. Progress Report of the Department of Heavy-Ion Physics, Institute of Physics, Bucharest, 1990-91, p.27.
3. The Cross-Sections of Some Alpha-Particle Reactions. By V. Avrigeanu, N. Ferdous and P.E. Hodgson. Progress Report of the Department of Heavy-Ion Physics, Institute of Physics, Bucharest, 1990-91, p.28.
4. Alpha-Particle Momentum Distribution in Nuclei within the Coherent Density Fluctuation Model. By A.N. Antonov, P.E. Hodgson, G.A. Lalazissis, E.N. Nikolov and I. Zh. Petkov. Proceedings of the Second Hellenic Symposium on Nuclear Physics. 12-13 April 1991. Edited by G.S. Anagnostatos, D. Bonatsos and E. Mavrommatis, p.397.
5. Nuclear Matter Distributions. By P.E. Hodgson. *Hyperfine Interactions* 74, 75, 1992.
6. Statistical Multistep Direct Calculations for (p, p') Continuum Spectra up to 200 MeV. By W.A. Richter, A.A. Cowley, R. Lindsay, J.J. Lawrie, S.V. Förtsch, J.V. Pilcher, R. Bonetti and P.E. Hodgson. *Phys. Rev. C* 46, 1030, 1992.
7. Semi-classical and Quantum Mechanical Pre-Equilibrium Neutron Emission. By M. Avrigeanu, P.E. Hodgson and A.J. Koning. *J. Phys. G* 19, 745, 1993.
8. The Microscopic Alpha-Alpha Potential. By P.E. Hodgson and S.A. Sofianos. Proceedings of the International Symposium on Microscopic Cluster Models of Light Nuclei and Related Topics, Yukawa Institute for Theoretical Physics, Kyoto, 31 August to 2 September 1992, B210, 1993.
9. Dispersion Relation Analysis of the Elastic Scattering of Alpha-Particles by ^{40}Ca . By P.E. Hodgson and W. Haider. Proceedings of the International Symposium on Microscopic Cluster Models of Light Nuclei and Related Topics, Yukawa Institute for Theoretical Physics, Kyoto, 31 August to 2 September 1992, B222, 1993.
10. Nucleon Correlations in Nuclei. by A.N. Antonov, P.E. Hodgson and I.Zh. Petkov. Springer-Verlag, 1993.
11. Multistep Compound Reaction Calculations Using the Feshbach-Kerman-Koonin Theory. By H.B. Olaniyi, P. Kanjanarat and P.E. Hodgson. *J. Phys. G* 19, 1029, 1993.
12. A Survey of Alpha-Clustering. By P.E. Hodgson. Invited paper given at the Second International Conference in Atomic and Nuclear Clusters, Santorini, Greece, 28 June to 2 July, 1993.

II. WORK RECENTLY COMPLETED AND IN PROGRESS

1. **Semi-Classical and Quantum-Mechanical Pre-Equilibrium Neutron Emission**
(M. Avrigeanu, P.E. Hodgson and A.J. Koning)
The energy and angular distributions of pre-equilibrium neutrons from the interaction of 14 MeV neutrons with target nuclei from ^{51}V to ^{58}Ni are analysed by the multistep compound (MSC) and multistep direct (MSD) theory of Feshbach, Kerman and Koonin (FKK) and the semi-classical Geometry-Dependent Hybrid (GDH) model. The same parameter sets were used for both calculations. The calculations are compared with experimental data and the applicability of the theories assessed.
2. **Multistep Compound Reaction Calculations using the Feshbach-Kerman-Koonin Theory**
(H.B. Olaniyi, P. Kanjanarat and P.E. Hodgson)
The cross-sections of (n, n') and (n, p) reactions at 14 MeV on a range of nuclei are analyzed using the theory of Feshbach, Kerman and Koonin. The contributions of the multistep compound and multistep direct processes are evaluated, and the strength of the effective nucleon-nucleon potential determined for both the zero-range and Yukawa potentials. (Published in *Journal of Physics B*).
3. **The Microscopic Alpha-Alpha Potential**
(S.A. Sofianos, K.C. Panda and P.E. Hodgson)
The alpha-alpha potential is derived from the Skyrme effective nucleon-nucleon interaction using the folding model and the energy density model with density-dependent terms and also the resonating group model. The unphysical Pauli states occurring in some of these potentials were removed using the Marchenko inversion method and the supersymmetric transformation. This gives an alpha-alpha potential that is both microscopically-based and consistent with the experimental data. The off-shell characteristics of this potential are studied and their importance for various reactions discussed. (Published in *Journal of Physics B*).
4. **The Feshbach-Kerman-Koonin Multistep Direct Reaction Theory**
(R. Bonetti, J.M. Akkermans, A.J. Koning and P.E. Hodgson)
The multistep direct reaction theory of Feshbach, Kerman and Koonin is described in detail and compared with other theories. The results of several analyses of experimental cross-sections are described, and the validity and usefulness of the theory assessed. (Review article in preparation for *Physics Reports*).
5. **Analysis of Neutron Inelastic Scattering Using the Feshbach-Kerman-Koonin Multistep Reaction Theory**
(P. Demetriou, P. Kanjanarat and P.E. Hodgson)
The data of Takahashi are being analysed using the multistep compound and multistep direct theories.
6. **Alpha-Particle Reactions**
(V. Avrigeanu, M. Avrigeanu and P.E. Hodgson)
The alpha-particle potentials obtained by N. Ferdous are being used to calculate the cross-sections of (α, n) and (n, α) reactions.

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The Nuclear Theory and Applications Group at Los Alamos is involved in the evaluation and calculation of nuclear data for applications, as well as the development of nuclear theory and models for this purpose.

I. Recent Publications and Reports

The following papers were presented at the OECD/NEANSC Specialist's Meeting on Fission Product Nuclear Data, Tokai, Japan, 25-27 May 1992, and appear in the Proceedings from that meeting (NEA/NSC/DOC(92)9):

T. R. England and B. F. Rider, "ENDF/B Yield Evaluation for 1992: Methods and Content," p. 346.

T. R. England and B. F. Rider, "Yield Validation: Integral Comparisons," p. 378.

W. B. Wilson, T. R. England, and D. C. George, "Sensitivity of Fission-Product Neutron Absorption to ENDVB-IV, -V, and -VI Nuclear Parameters," p. 450.

W. B. Wilson and T. R. England, "Nuclear Data Needs for Studies of Accelerator Induced Neutron Transmutation of Wastes," p. 475.

R. E. Schenter and W. B. Wilson, "Fission Product Data Requirements for Medical Application," p. 482.

The following papers were presented at the Symposium on *Nuclear Data Evaluation Methodology*, Brookhaven National Laboratory, Upton, NY, 12-16 October 1992, and appear in the Proceedings of the symposium (Editor: C. L. Dunford, World Scientific Press, Singapore, 1993):

G. M. Hale, "Use of R-Matrix Theory in Light Element Evaluations," p. 306.

P.G. Young and R.E. Shamu, "Methods in Coupled-Channel Optical Model Analysis of $n - {}^{208}\text{Pb}$ Scattering at Low Energies," p. 365.

D. G. Madland, "Theoretical Models of Neutron Emission in Fission," p. 401.

M.B. Chadwick and P.G. Young, "Application of Multistep Compound and Multistep Direct Models for Data Evaluation," (invited), p. 424.

P.G. Young, M.B. Chadwick, and M. Bozoian, "Use of the Nuclear Model Code GNASH to Calculate Cross Section Data at Energies up to 100 MeV," (invited), p. 480.

T. R. England et al., "Decay Data Evaluation for ENDF/B-VI," p. 611.

Description of Covariance Data in ENDF-6 Format," p. 689.

The following papers were given at the IAEA 2nd Research Coordination Meeting of the Coordinated Research Program on *Activation Cross Sections for the Generation of Long-Lived Radionuclides*, San Diego, CA, 29-30 April 1993 and will appear in the proceedings from that meeting:

M. B. Chadwick and P. G. Young, "Comparison of 14-MeV Isomer Production of $^{178m2}\text{Hf}$ and $^{179m2}\text{Hf}$ Using Feshbach-Kerman-Koonin and Exciton Preequilibrium Models," (LA-UR-93-3632).

M. B. Chadwick, M. Gardner, D. Gardner, O. T. Grudzevich, A. V. Ignatyuk, J. W. Meadows, A. Paschenko, N. Yamamuro, and P. G. Young, "Intercomparison of Theoretical Calculations of Important Activation Cross Sections for Fusion Reactor Technology," (LA-UR-93-3633).

Other publications:

P. G. Young, "Key Changes in Nuclear Data in the Transition from ENDF/B-V to ENDF/B-VI," (invited), *Proc. American Nuclear Society Meeting on New Horizons in Radiation Protection and Shielding*, Pasco, Washington, 26-30 April 1992 (LA-UR-91-2938), p. 372.

W. B. Wilson and T. R. England, "Development and Status of Fission-Product Yield Data and Applications to Calculations of Decay Properties," *Trans. Am. Nucl. Soc.* **66**, 152 (1992).

T. R. England, M. C. Brady, and B. F. Rider, "Recent Advances in US Fission Yield and Delayed Neutron Evaluations," *Trans. Am. Nucl. Soc.* **66**, 508 (1992).

M. B. Chadwick and P. G. Young, "Feshbach-Kerman-Koonin Analysis of ^{93}Nb Reactions: $P \rightarrow Q$ Transitions and Reduced Importance of Multistep Compound Emission," *Phys. Rev. C.* **47**, 2255 (1993).

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M. B. Chadwick and P. G. Young, "Calculation of Nuclear Data for Incident Energies to 200 MeV with the FKK-GNASH Code System," *Proc. Workshop on Simulating Accelerator Radiation Environments*, 11-15 January 1993, Santa Fe, New Mexico, to be published.

R. Kozack and D. G. Madland, "Parameter Correlations and Ambiguities in Dirac Phenomenology," *Nucl. Phys. A* **552**, 469 (1993).

B. A. Nikolaus, D. G. Madland, and T. Hoch, "Nuclear Ground State Properties in a Relativistic Point Coupling Model," *Phys. Rev. C* **46**, 1757 (1992).

D. G. Madland, T. Hoch, B. A. Nikolaus, and P. Manakos, "Ground State Properties of Exotic Nuclei in a Relativistic Point Coupling Model," presented at the 6th Int. Conf. on Nuclei Far from Stability and the 9th Int. Conf. on Atomic Masses and Fundamental Constants, Bernkastel-Kues, Germany, 19-24 July 1992 (Ed: R. Neugart and A Wöhr, IOP Publishing Ltd., 1993) p. 97.

The following papers will be presented at the International Conference on Nuclear Data for Science and Technology, 9-13 May 1994, Gatlinburg, Tennessee, USA:

P. G. Young and M. B. Chadwick, "Improvements to the Nuclear Model Code GNASH for Cross-Section Calculations at Higher Energies."

S. M. Sterbenz, F. B. Bateman, T. M. Lee, R. C. Haight, R. C. Goekner, C. E. Brient, S. M. Grimes, H. Vonach, P. Maier-Komor, P. G. Young, and M. B. Chadwick, "The $^{56}\text{Fe}(n,\alpha)$ Reaction from Threshold to 30 MeV."

T. M. Lee, F. B. Bateman, P. G. Young, *et al.*, "The $^{59}\text{Co}(n,\alpha)$ Reaction from Threshold to 30 MeV."

H. Hitzengerger, A. Pavlik, H. Vonach, R. C. Haight, R. O. Nelson, and P. G. Young, "Study of $^{27}\text{Al}(n,x\gamma)$ Reaction up to $E_n = 400$ MeV."

G. M. Hale, P. G. Young, and M. B. Chadwick, "Cross Sections for $n+^{14}\text{N}$ from an R-Matrix Analysis of the ^{15}N System."

A. Pavlik, H. Vonach, M. B. Chadwick, R. C. Haight, S. A. Wender, P. G. Young, $^{207,208}\text{Pb}(n,x\gamma)$ Reactions for Neutron Energies up to 200 MeV."

M. B. Chadwick, M. Blann, G. Reffo, and P. G. Young, "Model Calculations of Nuclear Data for Biologically-Important Nuclei."

D. G. Madland, "Calculation of Prompt Fission Neutron Spectra and Average Prompt Neutron Multiplicities for the Spontaneous Fission of Selected Actinide and Transactinide Nuclei."

D. W. Muir and G. M. Hale, "Parameter-Based Covariances of Evaluated Data for Neutrons Incident on ^1H and Other Important Nuclear Data."

G. M. Hale and T. L. Talley, "Cross Sections and Spectra for Charged-Particle Induced Reactions."

R. E. MacFarlane, "Energy Balance of ENDF/B-VI."

R. E. MacFarlane, "Data Testing of ENDF/B-VI."

II. Work Recently Completed

New R-matrix analysis completed of $n + {}^{14}\text{N}$ reactions to 2.5 MeV and incorporated into the ENDF/B-VI.2 evaluation.

New evaluations for 50 sets of cumulative and independent yields (34 fissioning nuclides at one or more neutron-induced energies and spontaneous fission) and 10 new sets for ENDF/B-VI were released in June 1993.

See publications.

III. Work in Progress

Extension of ENDF/B-VI evaluations of neutron reactions on ${}^2\text{H}$, ${}^{27}\text{Al}$, ${}^{56}\text{Fe}$, ${}^{59}\text{Co}$, and ${}^{208}\text{Pb}$ to 40 MeV.

Calculation of proton, alpha, and gamma-ray emission spectra from Al, Fe, Co, and Pb targets with incident neutron energies up to 200 MeV for comparison with measurements at WNR.

Calculation of prompt fission neutron spectra and average prompt neutron multiplicities for selected actinide and transactinide nuclei pertinent to nuclear applications and waste management.

Self-consistent calculations of neutron fission cross sections for the heavy isotopes of uranium and plutonium.

P_n values are being reevaluated and new six-group delayed neutron parameters for 43 fuels generated for a mod of ENDF/B-VI.

Working with the University of Lowell on analysis of new decay heat and delayed neutron measurements at short cooling times.

IV. Work Planned for the Future

Theoretical analyses and evaluations will continue for materials not included in the first issue of ENDF/B-VI.

Model and nuclear theory development effort into the medium-energy range will continue.

Full Hauser-Feshbach calculation of neutron and gamma-ray spectra from fission.

Continuing work on activation, actinide and fission-product decay and yield data, and data testing.

V. Work on Codes

CINDER'90: expanded capabilities and libraries for various CINDER version using ENDF/B-VI data.

GNASH and FKK-GNASH: being utilized for incident nucleon energies to 200 MeV in NEA-sponsored code comparison activities and in analyzing WNR measurements to improve modeling capabilities at higher energies.

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I. Recent Publications and Reports

Nuclear Data Evaluation and Methodology, Proceedings of the Symposium held at Brookhaven National Laboratory, 12 - 16 October 1992, published by World Scientific Publishing Co., 1993.

II. Work Recently Completed

ENDF/B-VI Nuclear Data Library, Release 2, was distributed in June, 1993. The release contains nine tapes and 87 materials: 43 materials in the neutron sublibrary, 31 for the FPY sublibrary, 9 for the spontaneous FPY sublibrary, 1 for the decay data sublibrary, and 3 for the proton sublibrary. New evaluations for ^{45}Sc and ^{127}I are included, plus high energy reactions for ^{12}C , ^{208}Pb , and ^{209}Bi . ^{14}N has been revised in the resonance region and extended to higher energies.

III. Status of ENDF Codes

The ENDF Utility codes release, version 6.9, has been completed and distributed. These programs are written to process ENDF-6 formatted files, including all formats approved through the May 1992 CSEWG Meeting.

IAEA Nuclear Data Section

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Selected meetings and resulting reports:

- Comparison of activation cross-section measurements and experimental techniques. Tokai, Japan, 15-17 Nov. 1993. Report in preparation. Contact: A. Pashchenko.
- Standard input data sets for nuclear model computations of nuclear data. Sirolo (Ancona), Italy, 21-25 June 1993. Report INDC(NDS)-282 by G. Reffo, A. Pashchenko et al.
- Activation cross-sections for the generation of long-lived radionuclides, Del Mar, 29-30 April 1993. Reports INDC(NDS)-288 (summary) and INDC(NDS)-286 (papers) by A. Pashchenko.
- Compilation and evaluation of fission yield nuclear data. Vienna, 21-23 April 1993. Report in preparation. Contact: M. Lammer.
- Improvement of measurements, theoretical computations and evaluations of neutron induced helium production cross-sections. Debrecen, Hungary, 17-19 Nov. 1992. Report INDC(NDS)-273 by A. Pashchenko.
- Charged-particle and photonuclear data libraries for FENDL. Brookhaven, 8-9 Oct. 1992. Report INDC(NDS)-268 by A. Pashchenko.
- Nuclear data requirements for fission reactor decommissioning. Vienna, 7-11 Sept. 1992. Report INDC(NDS)-269, by N. Kocherov.
- Measurement and analysis of 14 MeV neutron-induced double-differential neutron emission cross-sections. Chiang Mai, 31 March - 2 April 1992. Report INDC(NDS)-272 by Wang Dahai.
- Reference nuclear parameter library for nuclear data computation. Vienna, 13-15 Nov. 1991. Report INDC(NDS)-266 by G. Reffo, A. Pashchenko et al.
- Nuclear data for neutron multiplication in fusion-reactor first-wall and blanket materials. Chengdu, 19-21 Nov. 1990. Reports INDC(NDS)-264 (Summary) and INDC(NDS)-281 (papers) by A. Pashchenko and D.W. Muir.

Data libraries and related publications:

- WRENDA 93/94 - World request list for measurements of nuclear data that are known with insufficient accuracy. Report INDC(SEC)-104 by N. Kocherov and P.K. McLaughlin.
- FENDL - evaluated nuclear data libraries for fusion applications. Contact: S. Ganesan.
- WIMS-D4 nuclear data library: Status report of the WIMS Library Update Project, report INDC(NDS)-290 by S. Ganesan.
- Handbook on Nuclear Data for Borehole Logging and Mineral Analysis. IAEA Technical Report No. 357, including PC diskette, by N. Kocherov.
- Absolute gamma branching ratios for fission products in the mass range 74-165. Report INDC(SWD)-24 by G. Rudstam.
- Evaluation of the reaction cross-sections of $Ti-46(n,2n)$ and $Fe-54(n,2n)Fe-53m+g$. Report INDC(CCP)-360 by S.A. Badikov, A.V. Ignatjuk, A.B. Pashchenko, K.I. Zolotarev.
- Index to nuclear data libraries available from the IAEA Nuclear Data Section. Document IAEA-NDS-7 Rev. 94/1 by H.D. Lemmel.
- Joint index to BROND-2, CENDL-2, ENDF/B-6, JEF-2, JENDL-3, IRDF-93. Document IAEA-NDS-107 Rev. 8 (Nov. 1993) by H.D. Lemmel.
- IAEA Nuclear Data Newsletter No. 18 (Nov. 1993) including: New nuclear data libraries received; recent INDC reports and other publications; index to the Russian "Yadernye Konstantye"; how to access NDIS, the online Nuclear Data Information System. Contact us, if you are not yet on the Newsletter distribution list.

Selected translations from Russian:

- G.N. Smirenkin: Preparation of evaluated data for a fission barrier parameter library for isotopes with $Z = 82-98$, with consideration of the level density models used. Report INDC(CCP)-359.
- A.B. Klepatskij et al.: Evaluated neutron data for U-233. Report INDC(BLR)-1.

ENDF codes:

Contact: P.K. McLaughlin

- ENDF Utility Codes from NNDC, new version 6.9, with document IAEA-NDS-29 Rev. 6.9
- ENDF Preprocessing Codes by D.E. Cullen, new 1994 version ("PRE-PRO 94") with document IAEA-NDS-39 Rev. 8.

New coordinated research programmes:

Contact: P. Oblozinsky

- * A Co-ordinated Research Programme (CRP) on "Measurement, Calculation and Evaluation of Photon Production Data" is being initiated by the IAEA Nuclear Data Section. The CRP should bring together experimenters, theorists and evaluators aimed to recommend improved evaluation procedures for photon production from (n,x γ) reactions. It should examine current status of measurements, calculations and evaluations of photon production data, work out procedures and methods to be recommended in future evaluations of such data, and improve selected photon production cross sections in internationally recognized general purpose nuclear data libraries. The first Research Co-ordination Meeting is preliminary envisaged to be held later this year in Vienna.
- * A Co-ordinated Research Programme on "Development of Reference Input Parameter Library (RIPL) for Nuclear Model Calculations of Nuclear Data" is being initiated. The goal of the CRP is to develop a starter file of the input parameter library. The file is designed to provide necessary input for nuclear reaction model calculations of nuclear data for incident energies up to about 30 MeV. The file should consist of 6 major subfiles: atomic masses and related data, discrete level schemes, average neutron resonances, optical model parameters, level densities (total, partial, fission), and gamma-ray strength functions. The first Research Co-ordination Meeting is preliminary envisaged to be held in autumn this year in Bologna.
- * A Co-ordinated Research Programme on "Establishment of an International Reference Data Library of Nuclear Activation Cross-Sections" has started. The goal of the CRP is to provide a universal database of neutron and charged particle nuclear activation cross-sections and related decay data for nuclear and fusion technology and for environmental protection and the estimate of potential radiation hazards connected with any kind of nuclear installation and technique. The first Research Co-ordination Meeting is preliminary envisaged to be held in Debrecen, Hungary 27-30 September 1994.

NEA Evaluation Activities

A. JEF (Joint Evaluated File) project

Status

The new JEF-2.2 Radioactive Decay Data (Tape 22) and Fission Product Yields (Tape 24) sublibraries were released in July and June of 1993, respectively.

The complete JEF-2.2 library now consists of:

(Tape 1-9)	General Purpose Library	-	Dist-Jan92
(Tape 21)	Thermal Scattering Law data	-	Dist-Nov90
(Tape 22)	Radioactive Decay Data	-	Dist-Jul93
(Tape 24)	Fission Product Yields	-	Dist-Jun93
(Tape 25)	Photo-Atomic Interaction data	-	Dist-Aug90

JEF-2.2 (with distribution dates shown above) is an official release version of the JEF library (the first official release since JEF-1.1). Accordingly, accompanying documentation on the status and contents of the frozen library will be produced, and should be available by mid 1994.

Validation

The decay heat testing of the Radioactive Decay and Fission Yield data were completed in the summer of 1993. Benchmark testing of the General Purpose data in the thermal and fast range, and for shielding applications, is continuing. The J. Rowlands Pin-cell benchmark continues to provide good feedback on the different processing and calculational methods.

In general, benchmark testing of the JEF-2.2 library has revealed a number of areas where more work is needed in order to achieve the goal of having an evaluated data library suitable for differing applications without adjustment. However, a number of nuclear utilities in OECD member countries have already indicated an intention to adopt the JEF file as their standard reference library.

Plans for a JEF-3 library

The current JEF file will remain frozen with no further updates in the near term. Future work will be oriented towards long term improvements leading to a validated JEF-3 library by 1997. It is foreseen that the main areas of activity for JEF-3 will include new work on, the structural materials Zr, Cr, Fe, and Ni, the major actinides $^{235,238}\text{U}$, $^{239,240,241}\text{Pu}$, the minor actinides ^{237}Np , $^{241,243}\text{Am}$, ^{233}U , ^{232}Th , ^{233}Pa , the fission products Pd and ^{99}Tc , and burnable poisons and absorbers. A number of EFF evaluations will be considered for JEF-3 including those for ^{56}Fe and the light elements Li, Be, Si, Al, Pb and Mo isotopes. The close cooperation between the JEF and EFF projects will continue, and a joint JEF-EFF file, based on JEF-3 and EFF-3, is still envisaged.

JEF-2.2 Nuclides Database

This PC package for displaying JEF-2.2 decay data is now available from the Data Bank. Through an interactive 'chart of the nuclides' display it allows fast and easy access to data on individual radionuclides, such as half-life, spin, mass, and decay modes. Gamma-ray, x-ray, and alpha-particle

emission energies and intensities plus their uncertainties are given for each nuclide. A listing of decay lines sorted by energy allows unknown decays to be identified. Data may be displayed in numerical or graphical form, or printed or spooled to disk files.

A second version of this package is currently under development. In addition to decay data, this package will also contain independent and cumulative yield data from the JEF-2.2 Fission Product Yields Library, and group cross section data (processed into 20 bins/decade) for all cross sections present in the JEF-2.2 General Purpose Library.

This package will be demonstrated at the Gatlinburg Nuclear Data Conference in May, and will be available for general release by Summer 1994.

NJOY User Group

A number of problems in NJOY processing of JEF-2 data have been reported; among them, processing of Zr, ^{16}O , and Si data by HEATR, processing of H in BROADR, and Fe-56 in UNRESR. Generic problems in HEATR and ACER are known to still exist. Other previously known problems, such as processing of ^{19}F data, and processing of resonance data in R-M formalism, have now been resolved. The latest information on problems and working solutions is available via the Los Alamos NJOY electronic bulletin board.

A new version of the code, NJOY-91.91, is now available from the NEA Data Bank. A new manual is in print and will be available shortly. It is hoped that, in future, NEA distribution of NJOY, and updates to the User Manual, will be possible via electronic networks.

The next release will be NJOY-94. This will include new modules for probability tables in the resonance energy region, and for the generation of thermal scattering law data. Other changes will be the inclusion of PostScript plotting capabilities, and a more modular structure for improved portability.

To facilitate quality assurance procedure, users are encouraged to submit test problems to the NEA (which will be passed on to R. MacFarlane) for consideration as test cases in future releases of NJOY. In each case, the scope and objective of the test case should be clearly specified.

Next Meeting

The next meeting of the JEF Working Groups on Benchmark Testing, Data Processing and Evaluations will be held at the NEA Data Bank on the 8th and 9th June 1994; the NJOY User Group will also meet at this time. The Scientific Coordination Group will meet on the 10th June 1994, in the same place.

B. Intermediate Energy Data

The increasing number of test and feasibility calculations of nuclear energy applications at intermediate energies imply the need for intermediate energy nuclear data in an evaluated form. A particularly interesting application is the transmutation of radioactive waste with a hybrid system of an accelerator and a nuclear reactor, using high-energy proton bombardment of a spallation target to generate a sufficiently intense spectrum for the transmutation of high-level radioactive material.

Within the framework of the Japanese OMEGA (Option Making Extra Gains of Actinides and Fission Products) project two reports have been written in which the present situation concerning nuclear data has been discussed. In the first report, *"Review of High Energy Data and Model Codes for Accelerator-Based Transmutation"* - NEA/NSC/DOC(92) 12, the necessary nuclear data are reviewed and the current status of available experimental data and nuclear model codes is established. The contents of the experimental nuclear database EXFOR have been presented in graphical format. The second report, *"Requirements for an Evaluated Nuclear Data File for Accelerator-Based Transmutation"* - NEA/NSC/DOC(93) 6, addresses the data needs in terms of an evaluated file. Furthermore, a global (ENDF-6) structure of intermediate energy data files is proposed.

The predictive power of the various nuclear model codes has been tested in the NEA Intermediate Energy Nuclear Reaction Code comparison, involving high-energy proton reactions on Zr and Pb. As a starting point, the EXFOR database will be extended with high energy experimental data for these nuclei.

During its 5th meeting, on June 16-17, 1993 in Aix-en-Provence, the NEANSC Working Party on Evaluation Cooperation has decided to form a subgroup on Intermediate Energy Nuclear Data (see below). After the first meeting of this subgroup in May 1994 in Gatlinburg, and the establishment of the results of the aforementioned code benchmark, serious intermediate energy data evaluation work may be initiated.

C. NEANSC International Evaluation Cooperation

The fifth meeting of the Working Party on International Evaluation Cooperation (IEC) was held at Aix-en-Provence, France on 16th and 17th June 1993. Representatives from the IAEA Nuclear Data Section and the Russian evaluation effort BROND participated for the first time. The invited representative from the Chinese CENDL project was unfortunately not able to come to the meeting.

The Working Party reviewed the status and future plans of the major evaluation projects. The coordinator of each subgroup presented a report on recent development and needs for further work. It was concluded that the following subgroups would either terminate their work in early 1994 or were redefined to long-term subgroups during the meeting:

- | | | |
|-------------|--|-----------------------------------|
| Subgroup 1. | Inter-comparison of files for ^{52}Cr , ^{56}Fe and ^{58}Ni . | (terminating) |
| Subgroup 2. | Generation of covariance files for ^{56}Fe and nat-Fe | (terminating) |
| Subgroup 3. | Actinide data in the thermal energy range. | (terminating) |
| Subgroup 5. | ^{239}Pu 1 - 100 keV fission cross section. | (terminating) |
| Subgroup 7. | Multigroup Cross Section Processing. | (redefined; see Subgroup B below) |
| Subgroup 9. | High Priority Request List for Data Needs in Future/Advanced Reactors. | (redefined; see Subgroup C below) |

The final reports for most of these subgroups would be presented at the next International Nuclear Data Conference in May 1994 in Gatlinburg, USA

The following subgroups would continue their work and progress would be reviewed at the next meeting of the Working Party:

- Subgroup 4. ^{238}U capture and inelastic scattering cross sections.
(capture part finished, inelastic continues)
- Subgroup 6. Delayed Neutron Data Benchmarking.
(on-going experimental and theoretical activities)
- Subgroup 8. Minor Actinide Data.
(graphical intercomparison terminated, validation of data to be performed)
- Subgroup 10. Fission Product Inelastic Scattering.
(awaiting experimental results)
- Subgroup 11. Inter-Comparison of the Resonance Region of ^{52}Cr , ^{56}Fe , and ^{58}Ni .
(good progress in for example data for ^{52}Cr)

Considering that at least six subgroups were terminating their work in 1994, the Working Party felt it timely to start new subgroups. After a thorough discussion it was agreed to initiate work on the following subjects:

- Subgroup 12. Nuclear Model Validation.
- Subgroup 13. Intermediate Energy Nuclear Data Evaluation.
- Subgroup 14. Kerma and Radiation Damage Evaluation.
- Subgroup 15. Self-shielding treatment in the unresolved resonance region.
- Subgroup 16. Nuclear Level Densities for model calculations of Neutron Induced reactions with ^{52}Cr , ^{56}Fe and ^{58}Ni

It was also recognised that some areas of activity was of a more long term nature. It was thus decided to distinguish these activities for the others by creating special subgroups identified by a letter instead of a number. The following were established:

- Subgroup A. Experimental activities.
- Subgroup B. Evaluated Data Formats and Processing for Application Libraries.
- Subgroup C. High Priority Request List.

Next Meeting

The Working Party will meet on 4th to 6th May 1994 in Oak Ridge, USA, in conjunction with the International Nuclear Data Conference in Gatlinburg, USA.

New at the Data Bank ...

Evaluated Data Libraries

BROND-2.2

The Russian evaluated neutron data library has been updated since its release in 1992 to satisfy the requirements for processing using NJOY-91. The library contains data for 121 materials from 1-H-1 to 96-Cm-244 in ENDF-6 format.

CENDL-2

The Chinese evaluated nuclear data file, released in 1991, was updated and supplemented in 1993. It contains 54 elements or isotopes from 1-H-1 to 98-Cm-249. All files are now in ENDF-6 format.

EFF-2.4

The latest version of the European Fusion File, EFF-2.4 (pointwise file), was frozen in February 1994. The library (Tapes 104, 204, 304 and 404) contains evaluations for 82 materials. The main changes since the last version are new or updated evaluations for Ar-36,38,40, Fe-56, Ni-58,60, Pb-0 and Mo-isotopes. General release of this file is expected in June 1994. Libraries of derived data (for transport, dosimetry and Monte Carlo applications) will also be created.

ENDF/B-VI (Release 2)

The ENDF/B-VI Nuclear Data Library, Release 2, was distributed in June 1993. This distribution includes new or revised evaluations for 40 materials in the Neutron sublibrary (Tapes 127, 128 and 129), 31 materials in the Neutron Fission Product Yield sublibrary (Tapes 130 and 131), 1 material in the Decay data sublibrary (Tape 210), and 9 materials in the Spontaneous Fission Product Yield sublibrary (Tape 211). This release also includes new evaluations for 3 materials in the ENDF/HE-VI neutron and proton sublibraries.

IRDF-90 v2

The International Reactor Dosimetry File (IRDF-90) version 2 contains 58 recommended neutron dosimetry cross sections for 39 target materials (all, except 2, with complete covariance information), compared with 49 reactions for 36 materials in version 1. It also contains damage cross sections for Fe, Cr and Ni, and neutron spectra for 10 benchmark neutron fields.

JEF-2.2

The JEF-2.2 Radioactive Decay Data (Tape 22) and Fission Product Yields (Tape 24) sublibraries were released in July and June of 1993. This release completes the current version of the JEF library. The JEF-2.2 version of the library is the first *official* release since JEF-1.1. All intermediate versions between JEF-1.1 and JEF-2.2 were unofficial and should be regarded as obsolete.

Photon-Electron Interaction Data

This is a package of 3 data libraries (the Evaluated Atomic Data Library, the Evaluated Electron Data Library, and the Evaluated Photon Data Library) from the Lawrence Livermore National Laboratory.

EADL-evaluated atomic subshell and relaxation data for isolated neutral atoms, including fluorescence yields, subshell parameters, radioactive and non-radioactive transition probabilities, and energy deposition terms.

EEDL-energy-dependent evaluated electron interaction cross-sections and related parameters for all elements from 1-H to 100-Fm.

EPDL-cross sections, from 10 eV to 100 GeV, average energy deposits, and form factors.

Other Data and Publications

MASSES

Tables of measured and recommended masses, separation energies and Q-values associated with "The 1993 Atomic Mass Evaluation" by G. Audi and A.H. Wapstra (Nucl. Phys. A565, 1 and 66 (1993)). The data are contained in 6 files, available via the Online Service.

CINDA-93

The 1993 issue of the Computer Index of Neutron Data is now available, and contains bibliographical references to microscopic neutron data published after 1987. The complete CINDA file, as of 1st May 1993, is contained in the archival issue CINDA-A (1990) plus the current issue CINDA-93.

WREND-93/94

The tenth edition of the World Request for Nuclear Data (INDC(SEC)-104) is now available. This request list is intended to serve as a guide to experimentalists, evaluators and administrators, when planning nuclear data programs, and contains 287 requests related to fission reactor technology, 292 requests related to fusion, 28 on safeguards, and 113 for other applications.

Data Testing and Processing Codes

ENDF Utility Codes Release 6.9

The latest version of this package was received in November 1993. It contains the data checking codes CHECKR, FIZCON, PSYCHE; the code INTER for retrieving thermal cross-sections and other data; graphical plotting subroutines PLOTEF, GRALIB, INTLIB; and the file maintenance and retrieval codes LISTEF, SETMDC, GETMAT and STANEF. The programs, written to process ENDF-6 formatted files, can process all formats approved up to and including the October 1993 CSWEG meeting except for the R-Matrix resonance region format and the generalised format for covariances. Release 6.9 contains

mainly corrections to the previous version.

ENDF Pre-processing Codes (PRE-PRO 94)

The 1994 version of the ENDF Pre-processing codes package is now available. This package contains the codes CONVERT, MERGER, LINEAR, RECENT, SIGMA1, LEGEND, FIXUP, GROUPIE, DICTION, MIXER, VIRGIN, COMPLIT, EVAPLOT, RELABEL, and SIXPAK. These are used mainly for: calculating cross-sections from resonance parameters; calculating angular distributions, group averages, mixtures of cross sections, etc; producing graphical plots and data comparisons.

In this version the codes have been expanded in capabilities to process all the newest ENDF/B-VI formats. Furthermore, they have been extensively improved in terms of speed, accuracy and machine independence, as well as correcting many problems which existed in previous versions.

NEA Online Services

During 1993, the online services were extended to include news and information on other NEA activities and publications in addition to the Data and Computer Program services traditionally offered. The following services are now available via the online system :-

Data base searches

The following databases can be searched by accessing the NEA Data Bank through Internet (Telnet to db.nea.fr) or through X25 ((208) 0921607751). Results from the searches are routed to users through Internet (SMTP or FTP) or Bitnet (Mail or Netdata). Full access to these services is available to registered users (send e-mail to posca@nea.fr or posca@fmeab51).

- Nuclear reaction data measurements (EXFOR)
- Nuclear reaction data bibliographical Index (CINDA)
- Nuclear reaction data evaluations (EVA: JEF, ENDF, ...)
- Nuclear structure data bibliographical index (NSR)
- Nuclear structure data evaluations (ENSDF)
- Miscellaneous nuclear data (NUDAT)

Chemical thermodynamic data (TDB)

- Computer Program Abstracts (CPSABS)
- Computer Program Requests (CPSREQ)
- Computer Program Retrievals (CPSRET)

News and information

Information on activities at the Nuclear Energy Agency is available in the form of files. The files can be accessed as follows:

- By e-mail through a file server: Send a mail to listserv@db.nea.fr or listserv@fmeab51 (put HELP in the Subject line).
- By login through Internet (Telnet to db.nea.fr) or X25 ((208)0921607751).
- By Internet FTP (to db.nea.fr, login ANONYMOUS, password OPEN).

It is also possible to subscribe to a general distribution list to obtain notification of any new or modified information. The notification is sent to users by Bitnet or Internet mail.

The following is a list of files currently available:

DBG030.ASC	User's guide to the Online Services
LIST.ASC	This list of files available
<i>Nuclear data files</i>	
CINDA.ASC	<i>Subdirectory --</i> News on neutron data index publication
ENSDF.ASC	News on Evaluated Nuclear Structure file
EVA.ASC	News on Evaluated file database updates
EXFOR.ASC	News on Experimental data compilations db
JEF-NEWS-6.ASC	JEF news Number 6
JEF.ASC	News on Joint Evaluated File status
NNDEN.ASC	Neutron data Evaluation Newsletter
NSR.ASC	Information on Nuclear Structure database
NUDAT.ASC	Information on the Nuclear Data database
MASSES-INFO.ASC	General information on nuclear masses
MASS_EXP_MAS93.ASC	Measured nuclear masses
MASS_RM D_MAS93.ASC	Recommended nuclear masses
RCT1_EXP_MAS93.ASC	Measured reaction and separation energies. -1
RCT1_RMD_MAS93.ASC	Recommended reaction and separation energies.-1
RCT2_EXP_MAS93.ASC	Measured reaction and separation energies. -2
RCT2_RMD_MAS93.ASC	Recommended reaction and separation energies.-2
WRENDA.ASC	Information on World data request list
<i>Nuclear law files</i>	
<i>Subdirectory --</i>	
NLBINDEX.ASC	Nuclear Law Bulletin index
NLBRUSSELS.ASC	Text of the Brussels convention
NLINFO.ASC	Information on Nuclear Law documents
NLJOINT_PROT.ASC	Text of the Joint protocol
NLPARIS_CONV.ASC	Text of the Paris convention
NLPARIS_MOTIF.ASC	Motifs of the Paris Convention
<i>General files</i>	
<i>Subdirectory --</i>	
NEWSHELP.ASC	Information on online services
NEWSMAIL.ASC	Data Bank staff names and telephone nbs
NEWSMEETINGS.ASC	Information on upcoming meetings
OECD.ASC	OECD in brief
ORDER.ASC	Order form for NEA publications
PUBCAT.ASC	NEA Publications catalog
<i>Computer Program Service files</i>	
<i>Subdirectory --</i>	
NEWSPROGRAMS.ASC	News on Computer Program Services
CPSABS_*.ASC	Index to programs by category
<i>Radioactive waste management files</i>	
<i>Subdirectory --</i>	
RWBULLETIN.ASC	Nuclear Waste Bulletin - June 1992
RWINFO.ASC	Information available on Rad. Waste Mgt.

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